

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	110	(donald with s with gardner)	US-PGPUB; USPAT	OR	ON	2007/06/05 10:09
L2	79	1 and @ad<"20031231"	US-PGPUB; USPAT	OR	ON	2007/06/05 10:12
L3	10	2 and SiGe	US-PGPUB; USPAT	OR	ON	2007/06/05 10:07
L5	2	3 and optical	US-PGPUB; USPAT	OR	ON	2007/06/05 10:12
L6	2	5 and well	US-PGPUB; USPAT	OR	ON	2007/06/05 10:08
L7	16	(donald with s with gardner)	USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/06/05 10:09
L8	0	(donald with s with gardner) and SiGe	USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/06/05 10:09
L9	0	(donald with s with gardner) and quantum	USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2007/06/05 10:09
L10	0	(optical\$2 and modulator and SiGe and quantum and nano\$7 and electroabsorption).clm.	US-PGPUB; USPAT	OR	ON	2007/06/05 10:11
L11	3	(optical\$2 and modulator and SiGe and quantum and nano\$7).clm.	US-PGPUB; USPAT	OR	ON	2007/06/05 10:11
L12	2	11 and @ad<"20031231"	US-PGPUB; USPAT	OR	ON	2007/06/05 10:28
L13	3248	257/14,18,19,81,85,94.ccls.	US-PGPUB; USPAT	OR	ON	2007/06/05 10:28
L14	2487	13 and @ad<"20031231"	US-PGPUB; USPAT	OR	ON	2007/06/05 10:12
L15	111	14 and optical\$2 and SiGe	US-PGPUB; USPAT	OR	ON	2007/06/05 10:29
L16	84	15 and quantum	US-PGPUB; USPAT	OR	ON	2007/06/05 10:29
L17	19	16 and modulator	US-PGPUB; USPAT	OR	ON	2007/06/05 10:13
L18	12	17 and nano\$7	US-PGPUB; USPAT	OR	ON	2007/06/05 10:29

EAST Search History

L19	2135	438/32,46,47,77,93,94.ccls.	US-PGPUB; USPAT	OR	ON	2007/06/05 10:28
L20	1755	19 and @ad<"20031231"	US-PGPUB; USPAT	OR	ON	2007/06/05 10:29
L21	111	15 and optical\$2 and SiGe	US-PGPUB; USPAT	OR	ON	2007/06/05 10:29
L22	84	21 and quantum	US-PGPUB; USPAT	OR	ON	2007/06/05 10:29
L23	47	22 and nano\$7	US-PGPUB; USPAT	OR	ON	2007/06/05 10:29
L24	35	23 not 18	US-PGPUB; USPAT	OR	ON	2007/06/05 10:29

DOCUMENT-IDENTIFIER: US 20020101895 A1

TITLE: Wavelength-selective photonics device

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Application Filing Date - APD (1):

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Current US Classification, US Secondary
Class/Subclass - CCSR (1):

257/14

Current US Classification, US Secondary
Class/Subclass - CCSR (3):

257/94

Summary of Invention Paragraph - BSTX (8):

[0007] In spite of continued research efforts, efficient light emission has remained an elusive prospect for silicon devices and technologies, due to the indirect band-gap of silicon. It was only fairly recently that efficient light absorption and emission, including lasers, were achieved with devices whose operating principles made them independent of the band-gap type and magnitude. Examples of these devices are the **Quantum** Well Infrared Photo-detector (QWIP) and the **Quantum** Cascade Laser (QCL) respectively.

Summary of Invention Paragraph - BSTX (9):

[0008] Band-gap engineering is also possible in the silicon materials system with Si.sub.1-xGe.sub.x (**SiGe**) and/or Si.sub.1-x-yGe.sub.xC.sub.y (SiGeC) films strained to the silicon lattice. However, the band offsets are small compared to those of the III/V materials, thereby limiting the energy of the opto-electronic transitions between bound states, that is, limiting the range of wavelengths for device operation.

Summary of Invention Paragraph - BSTX (31):

[0029] It is yet another object of the present invention to provide said novel photonic device architecture, operating as a "Wavelength-Selective Light-Valve", which can be combined with "Wavelength-Selective Reflectors", in such a way as to form "Wavelength-Selective Reflective Displays", and **optical** communications systems.

Brief Description of Drawings Paragraph - DRTX

(2):

[0033] FIG. 1A shows a schematic cross-sectional view of the device architecture according to the present invention, showing a two **Quantum** Wells with the same "Left Bi-Layer Contact" and the same "Right Bi-Layer Contact".

Brief Description of Drawings Paragraph - DRTX

(32):

[0063] FIG. 8D illustrates the application of the invention for use as an Image-Sensor monolithically integrated with a Solar-Cell, wherein the Image-Sensor is to operate on Inter-Subband Transitions or Intra-Subband Transitions (both abbreviated as "IST"), in quantized structures like "Multiple **Quantum** Wells" (MQWs) active-layers;

Brief Description of Drawings Paragraph - DRTX

(35):

[0066] FIG. 9A shows the layer stack of Wavelength-Selective Light-Valves combined with Wavelength-Reflectors made with Photonic Band-Gap (PBG) materials. The design of the Light-Valves and the Reflectors for operation with wavelengths in the visible range enables the fabrication of solid-state reflection displays. The design of the Light-Valves and Reflectors for operation in the Infra-Red enables the fabrication of opto-electronic components such as **Optical** Routers. Light-Valves with lateral dimensions considerably smaller than the wavelength of the photons to interact with, enable the dynamic formation of diffraction patterns, in which case it becomes possible to do "wavefront engineering", resulting in the capability to perform "beam shaping" and "beam steering".

Brief Description of Drawings Paragraph - DRTX

(36):

[0067] FIG. 9B shows an exemplary way to implement an **optical** router using Wavelength-Selective Light-Valves and Wavelength-Selective Reflectors made with Photonic Band-Gap (PBG) materials. This implementation differs from that of FIG. 9A in that light is coupled to the WASP Light-Valves through a waveguide rather than through free space.

Brief Description of Drawings Paragraph - DRTX

(38):

[0068] Advanced thin-film deposition techniques, such as Molecular Beam Epitaxy (MBE) and Atomic Layer Deposition (ALD) for example, enable the fabrication of very sophisticated doping and heterojunction profiles in the

direction of epitaxial growth. Quantum Wells (QWs) require reduced dimensionality in one direction only, and for that reason are then easy to be made with such techniques. Quantum Wires and Quantum Dots require "reduced dimensionality" in two or three directions, respectively. Therefore, examples of quantized structures will, by default, mean Quantum Wells. However, this should not be seen as a conceptual limitation. If and when it becomes equally easy to fabricate Quantum Wires and Quantum Dots, the same concepts can (with suitable adaptations) also be used to implement these new device concepts, which can use and take advantage of quantization in more dimensions.

Brief Description of Drawings Paragraph - DRTX
(50):

[0080] Keeping the barrier-layers thick enough to prevent tunneling, but decreasing the thickness of the active-layers, induces quantization of the energy levels allowed to electrons and holes, that is, to the formation of discrete subbands in the conduction- and in the valence-band. In this case, the vertical film stack will consist of a collection of Quantum Wells, having opto-electronic properties strongly dependent on the film thickness of the active-layer, the band-alignment between the active- and the barrier-layer, and the alloy composition of the active-layer itself.

Brief Description of Drawings Paragraph - DRTX
(71):

[0101] Charge carrier transport perpendicular to the QWs is possible if the insulator films are thin enough for large tunneling currents. Therefore superlattice devices with vertical charge carrier transport are possible with epitaxial layers of silicon and metal oxides. Opto-electronic devices making use of superlattices of silicon and wider band-gap materials have been proposed in prior art ["Quantum Parallel Laser: A Unipolar Superlattice Interminiband Laser"; L. Friedman, R. A. Soref, and G. Sun; IEEE Photonics Technology Letters, Vol. 9, No. 5, May 1997, pp. 593-595]. However, possibly because of fabrication-related problems these have never been experimentally demonstrated.

Brief Description of Drawings Paragraph - DRTX
(79):

[0109] The present invention departs in a fundamental way from prior art such as the OWIP [See for example "Intersubband Transitions in Quantum Wells: Physics and Device Applications I", H. C. Liu, and F. Capasso, Semiconductors and Semimetals, Vol 62, November 1999, Academic Press], the QCL [see for example "Intersubband Transitions in Quantum Wells: Physics and Device Applications II", H. C. Liu, and F. Capasso, Semiconductors and Semimetals, Vol 66, November 2000, Academic Press], and the OPL ["Quantum Parallel Laser: A

Unipolar Superlattice Interminiband Laser"; L. Friedman, R. A. Soref, and G. Sun; IEEE Photonics Technology Letters, Vol. 9, No. 5, May 1997, pp. 593-595], in the engineering of the band-alignment and work-function of the lateral contacts. QWIP and QCL do not have any lateral contacts at all. QPL suggests lateral contacts, but they are not specified, and there is omission on how transport is supposed to take place, as there are no band-diagrams or text explanation of the working principles of those contacts. This point is extremely important, as will be seen in the following paragraphs.

Brief Description of Drawings Paragraph - DRTX
(102):

[0132] FIG. 2A shows an exemplary implementation of the present invention for operation through Inter-Band Transitions, with a stack of multiple active-layers for different wavelengths. The different active-layers are made of Si, or **SiGe**, or SiGeC, or SiGeCSn random alloys and/or superlattices, with varying composition and/or profiles. In this example, the material used for the barrier-layer is Al.sub.2O.sub.3. FIG. 2B shows the band-diagram of a cross-sectional cut along the (vertical) direction of epitaxial deposition. FIG. 2C shows the band-diagram for one of the active-layers, in a reverse bias condition suitable for photo-detection, of a cross-sectional cut along the (horizontal) direction between the two contacts.

Brief Description of Drawings Paragraph - DRTX
(109):

[0139] The energy of the direct band-gaps can be changed by making the active-layers of the QWs with Si.sub.1-x-y-zGe.sub.xC.sub.yn.sub.z(SiGeCS- n) random alloys and/or superlattices. At the present it is not known how the incorporation of Sn to make SiGeCSn random alloys and/or superlattices, modifies the band-structure and the band-alignments with respect to silicon. It is also well known that for **SiGe** layers strained to silicon with very high Ge content, the band-structure of those layers becomes Ge-like. It is also well known that, similarly to Si, the smallest band-gap of Ge is indirect at E.sub.G=0.66 eV, but it is also known that Ge has direct band-gaps at E.sub..GAMMA.1=0.8 eV and E.sub..GAMMA.2=3.22 eV. The incorporation of carbon, to make SiGeC strained layers, can have two effects: the addition of carbon can, partially or fully, compensate the strain induced by germanium, and carbon may itself induce a reduction of the band-gap, through lowering the conduction-band with respect to silicon. These factors enable the engineering of the magnitude of the direct band-gaps of active-layers made with SiGeC, rather than pure Si, so that different wavelength ranges can be targeted with Inter-Subband opto-electronic transitions.

Brief Description of Drawings Paragraph - DRTX
(116):

[0146] It should also be noted that $\langle 100 \rangle$ is the axis of symmetry in the k-space for silicon. For this reason, for Intra-Subband Transitions, it is not possible to couple electromagnetic radiation perpendicular to the $\langle 100 \rangle$ in real space. However, according to prior art ["Calculation of the intersubband absorption strength in ellipsoidal-valley quantum wells" E. R. Brown, and S. J. Eglash, Phys. Rev. B, Vol. 41, Number 11, 15 April 1990-I, pp. 7559-7568] by forming the QWs on $\langle 111 \rangle$ -oriented silicon surfaces, it is possible to couple the electromagnetic radiation perpendicular to those surfaces, that is, to $\langle 111 \rangle$ surfaces. Conversely, for a Ge-like band-structure, having k-space symmetry along the $\langle 111 \rangle$ orientation, $\langle 100 \rangle$ is the preferred crystal orientation for coupling light perpendicularly to the substrate surface.

Detail Description Paragraph - DETX (1):

[0156] In prior art devices operating with intra-subband opto-electronic transitions, such as Quantum Well Infrared Photodetectors (QWIP) and Quantum Cascade Lasers (QCL), the transport of charge carriers takes place in the direction of epitaxial growth, that is, perpendicularly to the active-layer and barrier-layers defining the Quantum Wells. For that reason, for the operation of those devices there is a coupling between the band-gap engineering inducing the energy subbands, and the electric field applied across the QWs, which is required for the purposes of charge injection and extraction. Under these conditions, several compromises and tradeoffs have to be made when engineering the devices.

Detail Description Paragraph - DETX (4):

[0159] The lateral contacts in the Wavelength-Selective Photonic architecture of the invention allow and enable charge transport in the active-layers to be parallel to the barrier-layers, thereby removing constraints with respect to the band-alignment and thickness of the barrier-layers. Thus, there is a decoupling of the subband engineering in the vertical direction of epitaxial growth, from the horizontal charge transport, injection and extraction, in the active-layers. Therefore, very large barrier heights between the active- and the barrier-layers are enabled, for electrons and/or holes, effectively providing the best approximation possible to the "infinitely deep Quantum Well". This feature is highly desirable for very sharp opto-electronic transitions with very narrow linewidths, since it is a key factor for highly selective absorption and/or emission of photons.

Detail Description Paragraph - DETX (14):

[0169] The same device can also be optimized for other functionalities, such as Wavelength-Selective Light-Valves which can operate in visible spectrum, and/or with the IR and/or UV wavelengths. Light-Valves designed for different ranges of wavelengths can be used for displays, **optical** switches, **optical modulators and optical** routers, with the latter being especially useful for free-space and fiber-optics communications. Some system architectures for these applications may require the combination of the "Wavelength-Selective Light-Valves" with "Wavelength-Selective Reflectors", made possible with Photonic Band-Gap (PBG) materials. Tuning the Light-Valves and the Reflectors to the same wavelengths, enables completely new solutions for system design, such as Displays, **Optical** Routers, etc., and for integration with other devices.

Detail Description Paragraph - DETX (24):

[0179] Different ranges of wavelengths translate into different photon energies, which in turn may require different **Quantum** Well designs. For example, the energy of photons of the mid Infra-Red (IR) spectrum is typically less than 1 eV, which is less than the band-gap of bulk silicon. In order to absorb these wavelengths, Intra-Subband Transitions in the conduction-band (or in the valence-band) of silicon may be used. For these transitions, the conduction band-offset of the QW barriers required for absorption between bound states ("bound-to-bound" transitions) need to be only slightly larger than the energy of the photon. Band-offsets of such magnitude are easy to obtain with QW barriers made of insulators.

Detail Description Paragraph - DETX (64):

[0219] In order to increase the total absorption coefficient, it may be required to fabricate Multiple **Quantum** Wells (MQWs) with identical specifications. The exact number of QWs required can be different for each range of wavelengths to be filtered, as slightly different QW engineering parameters may lead to different fractional absorption coefficients.

Detail Description Paragraph - DETX (72):

[0227] Again, the reduced volume of the active-layer in the **Quantum** Wells, may require the fabrication of identical Multiple **Quantum** Wells in order to increase the absorption coefficient.

Detail Description Paragraph - DETX (92):

[0247] The insertion of **Quantum** Well(s) in a micro-cavity and further optimization of the subbands enables the fabrication of Wavelength-Selective Photonic LASERs.

Detail Description Paragraph - DETX (98):

[0253] The Light-Valve is transparent when photon-absorption is suppressed and it is opaque when photon-absorption is enabled. Since the number of absorbed photons can be increased with increasing number of QWs in the Multiple **Quantum** Well stack for a particular 25 wavelength, the On/Off ratio (opacity/transparency ratio) of the Light-Valve can be increased with more QWs for a particular wavelength.

Detail Description Paragraph - DETX (108):

[0263] Wavelength-Selective Multi-Spectral Light-Valves for **Optical** Communications

Detail Description Paragraph - DETX (110):

[0265] When a Light-Valve is in the transparency mode for a given wavelength, photons of that particular wavelength can travel through it with little or no absorption. When the Light-Valve is in the opacity mode a particular, photons of that particular wavelength are absorbed, and therefore the signal amplitude is strongly reduced. The incoming and outgoing signal may reach the "**modulator**" either by an **optical** fiber or some other kind of waveguide. Therefore, the sources of photons for each of the wavelengths (LASERs), can operate in a continuous mode and are not required to do the modulation themselves.

Detail Description Paragraph - DETX (112):

[0267] This scheme does not route all the photons of the incoming light beams into a single **optical** path but rather, distributes the incoming light beams through all possible **optical** paths. Therefore, through the controlling of the transparency and opacity states of the Light-Valves, there is control of which **optical** paths allow propagation of the light beams, and which do not. Because the outgoing light beams have just a fraction of the intensity of the incoming light beams regeneration of the **optical** signals after each port is likely to be necessary.

Detail Description Paragraph - DETX (114):

[0269] This is an "all-**optical**" routing scheme because even though the photons directed to the non-selected **optical** paths are photo-absorbed, that is, converted into electricity, the light beams travelling through the selected **optical** paths do so without conversion to electrical signals at any point.

Claims Text - CLTX (4):

3. A device as claimed in claim 1, wherein the active-layers are

dimensioned to adjust the **quantum** well depth, thereby controlling the absorbing and emitting properties for the layers, irrespective of the bulk properties of those films.

Claims Text - CLTX (11):

10. A device as claimed in claim 1, wherein all the active-layers are adapted to be **Quantum** Wells, whereby said active-layers have at least one of an adjustable absorption edge and an adjustable emission edge.

Claims Text - CLTX (14):

13. A device as claimed in claim 12, adapted for Image-Sensing and **Optical** Communications.

Claims Text - CLTX (16):

15. A device as claimed in claim 1, adapted for Solid-State Reflection Displays and **Optical** Communications.

Claims Text - CLTX (18):

17. A device as claimed in claim 16, adapted to be embedded with at least one of Photo-Detectors and Light-Valves for Image-Sensing, **Optical** Communications, and Solid-State Reflection Displays.

Claims Text - CLTX (20):

19. A device as claimed in claim 18, adapted for **Optical** Communications, and Solid-State Emission Displays.